Energy-efficient Data Transmission in Wireless Sensor Networks[1]

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The sensors are low-cost, low-power devices with short transmission ranges. A sensor network is composed of a large number of sensors that are densely deployed either inside the phenomenon or very close to it. With its self-organizing ability, the sensor network is established on an ad hoc basis without a predetermined topology, and thus it can be randomly deployed in inaccessible terrains. The nodes in a sensor network usually collaborate together to perform the tasks and send results to some special nodes, named sink nodes, which have relatively powerful computing and communication capabilities.

With the energy constrained nature of wireless sensors, it is a key design issue to make efficient use of battery power in order to increase their lifetime. In particular, since most of the energy of a sensor is spent on data transmission, which includes transmitting data generated by the node itself and the data relayed for other sensors, finding an optimal approach for data transmission is particular important. Furthermore, a sensor network is usually deployed as an integral entity to retrieve data in the area of interest. The lifetime of the whole sensor network is more important than those of individual nodes. An area that cannot be sensed by any nodes is called a blind area. If a blind area becomes too large, the data retrieved is unreliable and the sensor network cannot function properly.

The radio models of wireless sensor networks fall into two categories: direct transmission and multi-hop transmission. With the former model, a sensor transmits data directly to the sinks; while the latter approach follows multi-hop relaying between the sensors and the sink. With the network lifetime as the primary concern, however, neither of them is perfect. More specifically, the direct transmission drains significant power of the nodes far away from the sink because the wireless signals attenuate with the distance in an order of 2 to 4. The multi-hop transmission, on the other hand, consumes less power at each hop with the cost of increased total traffic in the sensor network. As a result, the nodes close to the sink have to carry more traffic and accordingly may drain off their battery power quickly.

In this work, we propose several efficient algorithms for optimizing the energy utilization and maximizing the lifetime of sensor networks. We consider two types of sensor networks, namely the even-driven network and the time-driven network. The sensors in the time-driven network generate data periodically at a constant rate and send the data to the sink. We propose an Integer Linear Programming (ILP) model, a Balance-based Energy-Efficient (BEE) communication protocol, and a Distributed Energy-Efficient Routing (DEER) protocol for prolonging the lifetime of the time-driven sensor network. While the ILP model is complex and time consuming, its solution shows the upper bound of the network lifetime. The BEE protocol is a centralized approach, based on our proposed path balancing and traffic splitting algorithms. DEER is a distributed routing protocol that makes energy-balanced routing decisions based on the local information. The sensor in an event-driven network generates datagrams and transmits them to the sink only when it senses the target event. As a result, the traffic is not predetermined and the data rate is not constant. Several heuristic algorithms are studies in our research and compared with the results obtained from the ILP model. Extensive simulations have been carried out to evaluate our proposed schemes. The simulation results show that the proposed approach can distribute energy consumption uniformly among the sensor nodes and achieve the optimal lifetime and connectivity of the entire sensor network.